POPULATION STRUCTURE, COMPOSITION AND ABUNDANCE OF ELEPHANTS *ELEPHAS MAXIMUS* IN MINNERIYA NATIONAL PARK, SRI LANKA

(*With six text-figures and one plate*)

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The Minneriya National Park was established mainly to enhance the long-term survival of the Asian elephant (*Elephas maximus*) in a predominantly agricultural area in Sri Lanka. The ancient reservoir, after which the Park is named, is seasonally home to large numbers of elephants because of the availability of water and the extensive areas of grassland created by fluctuations in the water level. In a preliminary study carried out from September 2000 to August 2001, a total of 974 elephants were recorded, of which 797 were classified according to age and sex. A quarter of the observations referred to solitary males. The most frequently observed grouping comprised 5-10 individuals that represent the family unit. The population structure appears to be equally divided between the adults and the other categories. The observed mean adult male:female sex ratio was 1:2.9, close to the national average of 1:3. Large groupings of elephant were observed when the drop in water level in the reservoir resulted in increase in the area of the grazing grounds. The largest group observed comprised 70 animals. There were also all-male groups, whose composition varied from 2-6. Most of the animals were observed emerging from the forest to feed on the grasslands between 1600-1700 hrs in the evening. During the rainy season, as the water level in the reservoir increased, flooding the grazing grounds, elephants moved to areas outside the Park, causing conflict with the farming community. The gradual build up of elephants in the Park leading to the observed maximum of 319 animals, translates into a crude density of 3.6 animals per sq. km, which is among the highest densities recorded in Asia. Therefore Minneriya National Park represents one of the important areas for elephant conservation in Sri Lanka. But the survival of the elephant outside the protected area can only be assured if appropriate measures are adopted to reduce the human-elephant conflict.

INTRODUCTION

Despite its small size, the island of Sri Lanka (65,610 sq. km) supports several viable populations of elephants estimated to number between 3,000 and 4,000 animals (Santiapillai and Jackson 1990). To conserve the elephant and other wildlife, Sri Lanka has set aside about 12.5% of the land area under protection. Outside the system of protected areas, a combination of high human population growth and deteriorating fertility of the land has led to increased encroachment and degradation of forests inhabited by the elephant and other wildlife. This has led to a build up of elephant numbers within the protected areas, while outside elephants are finding it increasingly difficult to move about and adjust their densities to seasonal changes in vegetation and water availability across their range. One of the more recent additions to the system of protected areas is the Minneriya National Park, opened to visitors on May 29, 1998. It is known to support high elephant numbers seasonally in response to changes in the water availability and grazing areas. However, given its central location in a predominantly agricultural area, conflict between

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man and elephant has become inevitable. No studies have so far been carried out on the ecology of the elephant in Minneriya National Park to document the seasonal build up of its numbers. It was to address these issues that a preliminary study was carried out from September 2000 to August 2001.

Study Area

The 8,889 ha Minneriya-Giritale Nature Reserve was established on February 12, 1988, and was subsequently upgraded to a National Park on August 12, 1997. It is situated next to the Minneriya-Giritale Sanctuary (6,693 ha), a part of which was designated as a national biosphere reserve (809 ha). The entire Minneriya-Giritale complex is situated in an important agricultural area in the Polonnaruwa district in the North Central Province of Sri Lanka (Fig. 1). The Park is named after the ancient irrigation reservoir Minneriya, built by King Mahasena in the 3rd century AD. It has a capacity of 2,250 ha when full and a catchment area of 24,000 ha. The main source of water is from a diversion of the Amban Ganga, along the Elahara Channel (IUCN 1990).

Grasslands and a belt of dry mixed evergreen forest surround the reservoir. The vegetation in the grasslands bordering the reservoir consists of species such as *Cynodon dactylon*, *Brachiaria mutica*, *Echinochloa colonum*, *Paspalum vaginatum* and *Digitaria longiflora*, many of which are truly hydrophytic. In addition, extensive patches of grasslands composed mainly of *Imperata cylindrica* (Illuk) and *Panicum maximum* (Pohon) are also common. The forest is dense with species such as *Drypetes sepiaria*, *Chloroxylon swietenia*, *Vitex altissima*, *Manilkara hexandra*, *Limonia acidissima*, *Diospyros ovalifolia* and *Berrya cordifolia*. The fauna includes not only the endangered species, the Asian elephant *Elephas maximus* and the leopard *Panthera pardus*, but also other mammals such as spotted deer *Axis axis*, sambar *Cervus unicolor*, barking deer *Muntiacus muntjak*, wild pig *Sus scrofa* and jackal *Canis aureus*. Both sloth bear *Melursus ursinus* and wild buffalo *Bubalus bubalis* are very rare in the Park, but domestic cattle range freely in large numbers.

The Park is also renowned for its rich and diverse waterfowl, both indigenous as well as migrant. Resident birds include the painted stork (*Mycteria leucocephala*), Asian openbill-stork (*Anastomus oscitans*), white-necked stork (*Ciconia episcopus*), and the lesser adjutant-stork (*Leptoptilos javanicus*). The reservoir itself supports a variety of economically important fishes such as *Labeo dussumieri*, *Puntius sarana*, *P. dorsalis*, *P. chola*, *Cyprinus carpio*, *Mastacembelus armatus*, *Ophicephalus striatus*, etc. (IUCN 1990). The annual rainfall for the year 2000 was 1,344 mm, and the principal rainy season extended from October to January. During the dry season, which lasts from February to September, the Park receives very little rainfall, and none at all in May, June and July. The average annual temperature is 27.2 °C.

Methods

All observations on elephants in Minneriya were made from a vehicle. We adopted the road-strip count method of Hirst (1969) to monitor the fluctuations in elephant numbers. The study area was visited at monthly intervals during which observations on elephants were made along a 14 km stretch of motorable forest track, through forest and grassland habitats. Although some animals were observed up to a maximum distance of 300 m, most of the observations fell within 200 m. As the elephants in Minneriya have been known to emerge from the forest predominantly during the evenings, all sightings of elephants were made between 1500 and 1900 hrs. At every sighting, the location of the elephants, their number, composition and activity were noted. For census purposes, the four categories recognised by Eisenberg and Lockhart (1972) — namely adult,

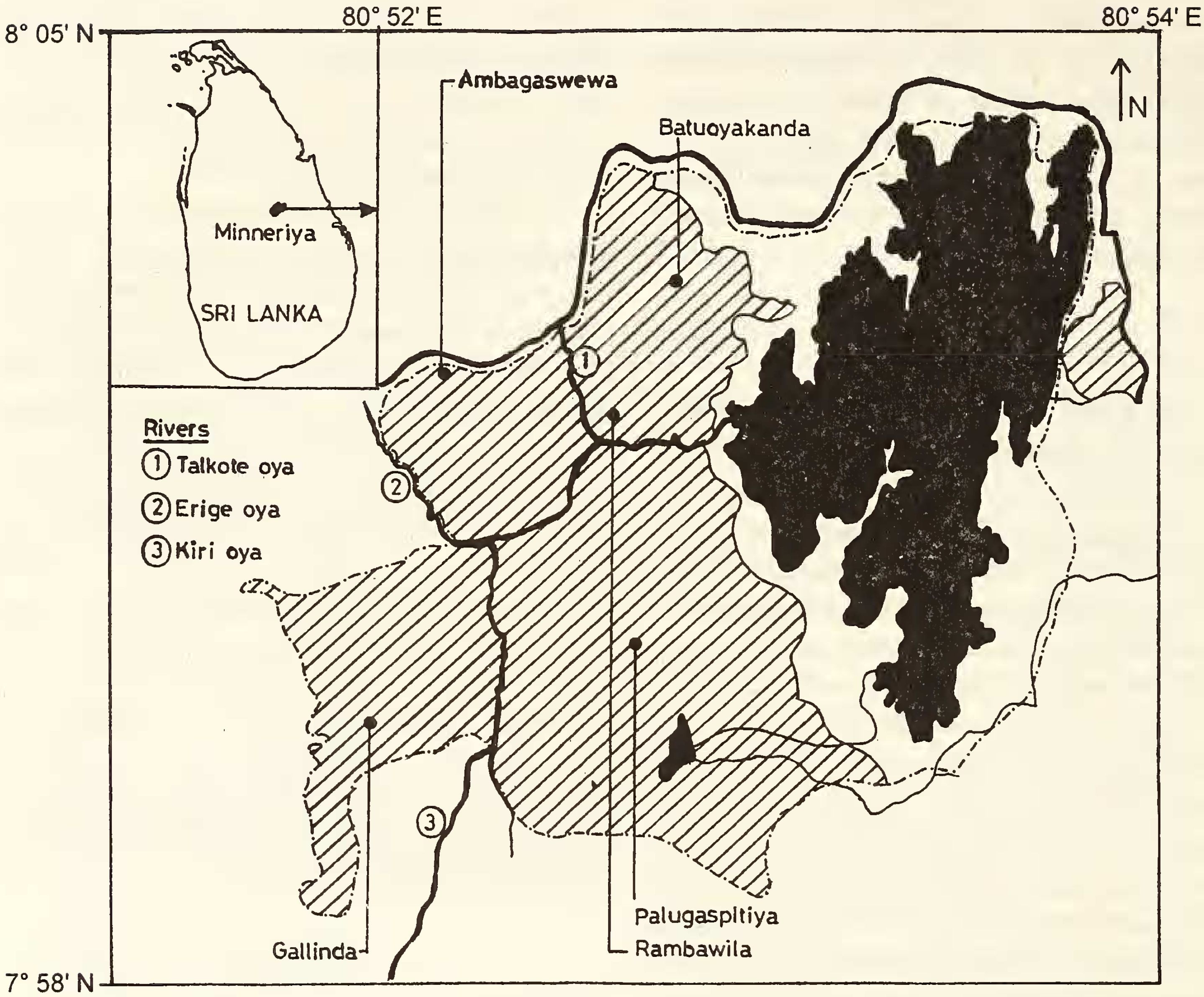

Fig.1: Map of Minneriya National Park, Sri Lanka, showing the reservoir (shaded area), grazing grounds (open area) and forest (cross-hatched area)

subadult, juvenile and calf — were adopted. A group of elephants refers to more than two animals of any age or sex moving together in a coordinated manner, while a family unit or herd refers to an integrated unit of closely related elephants of all classes excluding adult males (Laws 1970).

Results and Discussion

Population Structure

Between September 2000 and August 2001, a total of 974 elephants were sighted from 94 observations of which 797 animals were classified according to age and sex. Nine of the observations could not be classified. Of the 94 observations on elephants, 24 (or 25.5%) represented solitary individuals (adult or subadult males), and 10 (or 10.6%) referred to all-male groups, whose size ranged from 2-6 animals. A total of 51 family units were identified (Table 1), of which 25 (or 49%) had no adult bulls, while 8 (15.7%) had only one bull, 9 (17.6%) had two bulls, 4 (7.8%) had three bulls, 3 (5.9%) had four bulls, and 2 (3.9%) had eight bulls (Fig. 2). The association of bulls with family units was temporary and was related to the presence of oestrus females (Short 1966). In an extraordinary instance, there were 8 bulls associated with just two cows. Observations by Douglas-Hamilton (1972), Croze (1974), Laws *et al.* (1975) and Poole and Moss (1981) have largely dismissed the traditional view of a single bull being an integral part of a family unit to the exclusion of

Table 1: The composition of the family units of elephants in Minneriya National Park

Family unit	Adult males	Adult females	Subadults	Juveniles	Calves	Total
1	-	11	8	5	4	28
2	-	1	1	1	-	3
3	-	2	1	1	-	4
4	-	3	3	3	1	10
5	-	2	-	-	1	3
6	2	14	21	6	6	49
7	-	3	-	2	1	6
8	-	5	2	-	4	11
9	-	3	-	1	-	4
10	-	1	1	-	1	3
11	-	2	-	2	-	4
12	-	2	-	-	2	4
13	2	17	12	10	4	45
14	1	10	6	3	4	24
15	-	1	2	-	1	4
16	2	5	1	2	-	10
17	-	4	-	1	2	7
18	-	2	1	1	2	6
19	1	6	5	2	2	16
20	-	6	4	2	3	15
21	-	10	9	3	1	23
22	1	2	4	2	1	10
23	-	5	4	2	-	11
24	-	22	7	4	3	36
25	-	11	3	3	4	21
26	2	5	2	4	-	13
27	-	1	-	2	-	3
28	2	8	3	2	2	17
29	1	8	9	2	3	23
30	2	29	18	15	6	70
31	1	12	6	6	4	29
32	2	13	4	3	3	25
33	4	2	2	2	2	12
34	-	2	2	1	-	5
35	-	3	-	1	3	7
36	1	7	1	2	2	13
37	-	1	5	1	-	7
38	-	5	4	2	1	12
39	3	1	2	-	-	6
40	8	21	10	6	4	49
41	4	2	1	3	-	10
42	1	2	-	1	1	5
43	8	1	1	-	-	10
44	3	7	3	-	1	14
45	4	7	-	4	5	20
46	3	1	-	1	-	5
47	-	1	2	-	1	4
48	2	4	4	2	1	13
49	1	1	1	1	-	4
50	3	1	2	2	-	8
51	2	1	2	-	1	6
Total	66	296	179	119	87	747

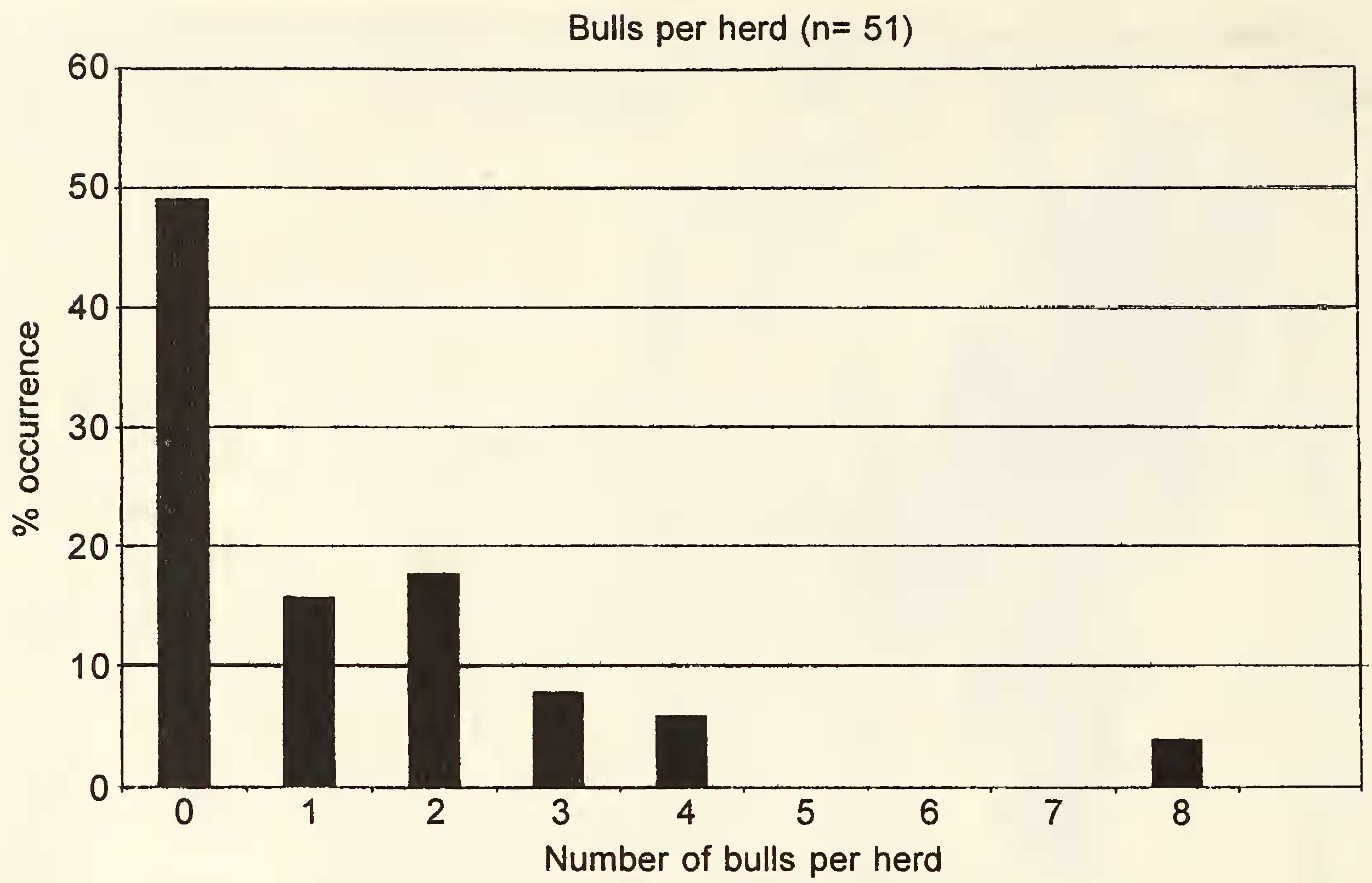

Fig. 2: The proportion of adult bulls in family units or herds observed in Minneriya National Park

other adult bulls (Rushby 1965, Sikes 1971, Poche 1974). Nevertheless, as Barnes (1982) points out, in situations where elephants form very large groups, it may pay for a bull elephant to exclude other bulls and remain with a group, given the opportunities available for mating with different females that come into oestrus. In such a situation, there is no need for the bull to move out in search of cows in heat. But in Minneriya National Park, given the small size of the groups, there would be no real advantage for a bull to be permanently associated with a group. In such a situation, the best strategy for a bull to enhance reproductive success would be to move from group to group in search of cows in oestrus. Monthly changes in structure and composition of the population of elephants are given in Table 2. As can be seen from Fig. 3, the population structure of elephants in Minneriya appears to be equally divided between adults and the other categories put together. Of the total 797 animals that were classified, 401 (or 50.3%) were adults (males, including solitary bulls, and females), while 190 (or 23.8%) were subadults and 206 (or 25.8%) were young animals (both juveniles and calves). Such an adult-dominated age structure is characteristic of several populations of elephants in Sri Lanka (Eisenberg and Lockhart 1972, McKay 1973, Nettasinghe 1973, Ishwaran 1981, Santiapillai *et al.* 1984, Katugaha *et al.* 1999). An age ratio of this type is to be expected in a species

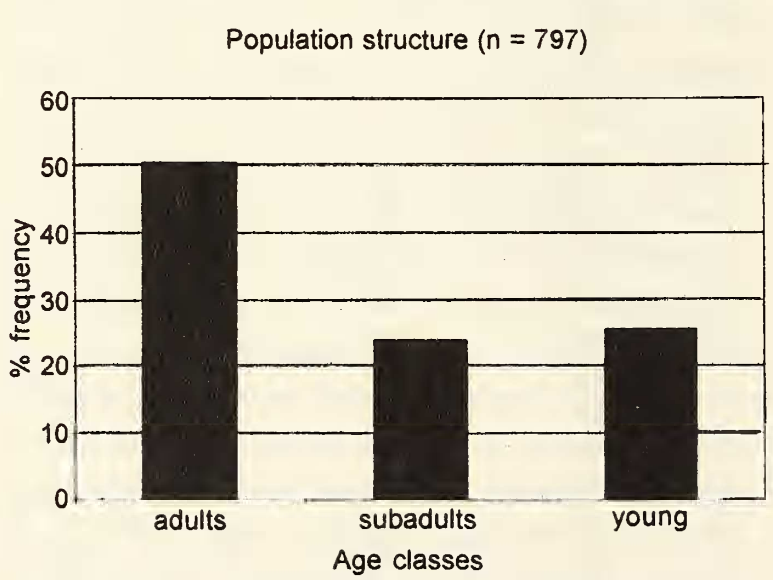

Fig. 3: The proportion of adults, subadults and young observed in the population of elephants in Minneriya National Park

Table 2: Monthly changes in population structure and composition of elephants in Minneriya National Park

Date 2000-01	Adult males	Adult females	Sub-adults	Juveniles	Calves	No. calves/ 100 cows	Total	(Unclassified)
September	10	76	58	34	28	36.8	206	(44)
October	16	80	45	28	19	23.8	188	(131)
November	9	70	40	28	18	25.7	165	-
December	0	0	0	0	0	0.0	0	-
January	4	2	2	2	2	100.0	12	-
February	0	0	0	0	0	0.0	0	-
March	3	0	0	0	0	0.0	3	-
April	1	0	0	0	0	0.0	1	(2)
May	3	0	1	0	0	0.0	4	-
June	7	5	3	2	3	60.0	20	-
July	2	8	6	3	2	25.0	21	-
August	48	57	35	22	15	26.3	177	-
Total	103	298	190	119	87		797	(177)

characterised by exceptional longevity, long gestation period and extended inter-calving intervals.

Sex-ratio

Among Asian elephants, the sex ratio does not appear to shift significantly from the expected 1:1 ratio until the subadult stage is reached (Sukumar 1989). The elephant being a polygynous, sexually dimorphic species, the adult sex ratio is unlikely to be in parity but varies considerably from place to place (McKay 1973), and is usually biased in favour of the females owing to a higher natural mortality in the males. As Sukumar (1989) points out, the sex ratio at stable age distribution will depend on the magnitude of the difference in mortality rates of male and female elephants, assuming an equal ratio at birth. Furthermore, the difference in the adult sex ratios in an area could be due to either a high mortality among males or through dispersion of the animals in space and time (McKay 1973). Thus, as Katugaha *et al.* (1999) point out, even under normal conditions, the sex ratios of progressive age classes would become increasingly female-biased in elephant populations. The observed mean adult male:female sex ratio in Minneriya, i.e. 1:2.9, is in keeping with the national average of 1:3 determined by McKay (1973), Kurt (1974) and Hendavitharana *et al.* (1994). However, within the family units, the ratio becomes slightly more biased in favour of the females 1:4.5 (Table 1), as several of them were not associated with bulls. The adult sex ratio is significantly biased in favour of the females in the months of September, October and November, during which the ratio ranged from 1:5 to 1:7.7 (Table 2). However, as Sukumar (1989) points out, since at any time, a proportion of the cows would be either pregnant or in lactation anoestrus, not all the adult females would be available for mating with the bulls. Hence, the operational adult sex ratio would not be as skewed as the one observed in the population. The observed adult sex ratios seem to indicate that the elephant population is not subject to very high mortality as a result of either poaching or conflict with man. Given the fact that females do not carry tusks and only a small proportion of the bulls (less than 7%) are tuskers in Sri Lanka, poaching for ivory is not the major cause for the disparate sex ratio. In Minneriya, there were only

4 tuskers: 2 juveniles and 2 adults. Both adults were single tusked, one being right tusked and the other left tusked, and so could easily be identified.

Group size

The most frequently observed grouping comprised 5-10 individuals that represented the family units or herds (Fig. 4). A number of family units associate temporarily to form the larger groupings seen in the Park. Family units vary in size from two (mother-calf units) to nine (three adult females with their offspring). The mean group size including solitary individuals is 10.4. If solitary individuals (i.e. bulls) are not taken into account, then the average group size increases to 13.6 (range 2-70). Of the 51 groups numbering more than three individuals, 25 (or 49%) had no adult bulls. The association of adult bulls with family units was common in the months from August to November. Large groups of elephants were observed following the build up of numbers around the Minneriya reservoir. The largest grouping consisted of 70 individuals. In addition, there were ten all male groups. These groupings appear to be temporary associations between sexually mature elephants held together by weak social bonds. They exhibit short-term cohesion. Such all male groups with rapidly shifting composition of individuals have also been recorded in Africa (Croze 1974). The maximum number of bulls seen together in Minneriya was six (range 2-6).

The composition of one of the groups (No. 43 in Table 1) that were observed in Minneriya National Park was rather strange. It had eight bulls and two cows. According to Dr. Phil Kahl (pers. comm.), who had studied the phenomenon of musth in African elephants, a possible explanation for such a strange grouping is that the older of the females was a cow in oestrus; the younger female, probably a previous calf of hers that was staying on with the mother. The 8 bulls were probably "suitors" hoping to mate with the adult

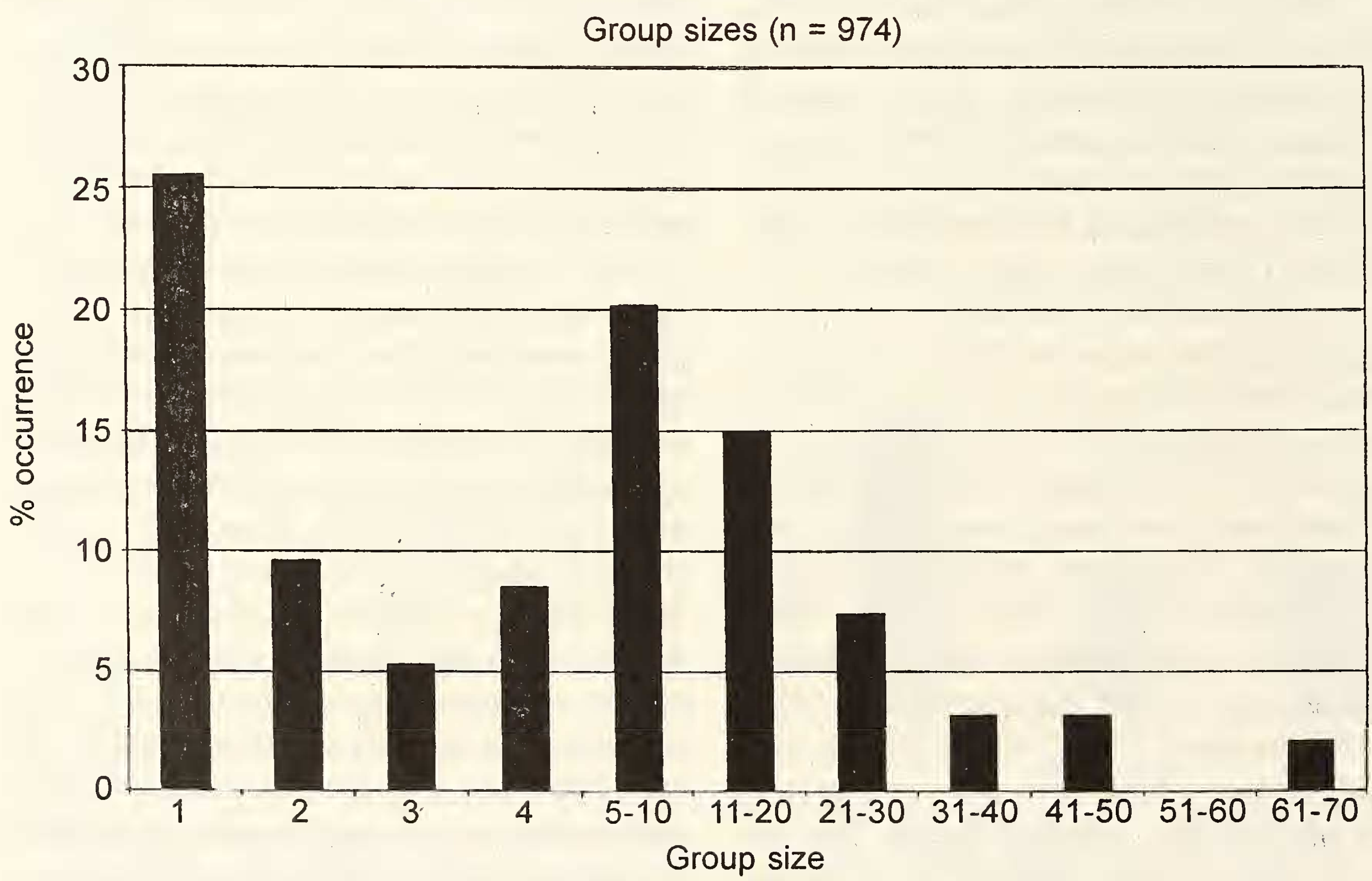

Fig. 4: Group size frequency diagram for elephants in Minneriya National Park

Santiapillai, Charles *et al.* : *Elephas maximus* PLATE 1

Fig. A: A herd of elephants around the biggest bull in Minneriya National Park, Sri Lanka

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Fig. B: An encounter between two bull elephants in Minneriya National Park, Sri Lanka

female. One of them might have been a bull in musth, in which case he would most likely have been in "consort" with the oestrous female.

The mean group size of elephants varies over time and space, and some of the variation could be related to the availability of food (Leuthold 1976, Barnes 1983, Dublin 1996). In Minneriya it appears that elephants range in small groups during the dry season when food is of poor quality. Olivier (1978) correlates the decline in mean group size with a decrease in the habitat quality. It appears that smaller units of elephants are perhaps better adapted to exploit a patchily distributed resource than are larger ones (White *et al.* 1993). Of the 33 family units having 10 or more animals that were recorded during the study, 31 (or 94%) were encountered during the rainy season, and only 2 (or 6%) were seen in the dry season. As Dublin (1996) argues, the formation of larger groups allows elephants to interact, to determine dominance hierarchies and to re-establish bonds. In Minneriya, there is a gradual build up of elephant numbers from August to November as animals move in from outside when many of the smaller water holes dry up in the neighbourhood. The large Minneriya reservoir provides a year-round supply of water. Even at the peak of the dry season, grasslands around the reservoir become grazing areas for hundreds of elephants. The surrounding mixed evergreen forest provides a variety of plants on which the animals browse. As the rainy season progresses, the water level in the reservoir increases substantially, leading to the flooding of the very grasslands that support large numbers of elephants in the dry season. As the water level increases, the elephants disperse to other areas outside the Park. It is during such times that the area experiences an increase in the conflict between man and elephant. It is also the time when paddy plants have been planted extensively, and these provide rich feeding areas for the dispersing elephants. As Laws (1974) argues, the group size is a measure of the ecological health of an elephant population, given that aggregations of family units and bull groups could be the result of stressful conditions. The stress may arise through nutritional deficiency or through the loss of matriarchs following hunting (Eltringham 1977). The habitat diversity of Minneriya National Park makes it unlikely that elephants may suffer from nutritional deficiency. None of the animals that were observed in the Park were in poor condition. Besides, as the Park itself is situated within an agricultural landscape, the elephants, especially the bulls, have the opportunity to supplement their diet with highly nutritious food plants cultivated by man. Therefore, it is social factors more than nutritional deficiency and loss of matriarchs from hunting, that may determine group sizes.

Feeding activity

The distribution of elephants in Minneriya National Park appears to be aggregated, which suggests that the area is not uniformly attractive to them. Much of the elephant feeding activity was centred round the grasslands. As all the elephants were observed in the open grasslands between 1500 and 1900 hrs, grazing was the most important activity recorded. As Katugaha *et al.* (1999) point out, groups of elephants usually spend a large part of their time during the day within the forests, under shade, and so are not noticeable until they move to the grasslands in the late evenings to graze. Although elephants spend considerable time in the woodlands, trees and shrubs make up only a small proportion of their food (Buss 1961). In Sri Lanka, grasses are the most important food of elephants. But elephants alter their food habits in relation to season. Fig. 5 summarises the feeding activity pattern of the elephants observed in Minneriya. The peak of the activity was observed between 1600 and 1700 hrs, when the highest number of elephants, 388 (39.8%) were recorded. The activity fell during the next hour (1700-1800 hrs) and picked up once again from 1800-1900 hrs.

Seasonal abundance

As can be seen from Fig. 6, the number of elephants utilising Minneriya National Park increased from August, reaching a peak in October 2000 when a total of 319 animals were recorded, and declined abruptly after November. The 8 month period from December to July was characterised by a great reduction in elephants or a total lack of them. Such a build up of elephant numbers in Minneriya is the result of two related phenomena: seasonality of rainfall, and the seasonal establishment of extensive grazing grounds as a result of the release of water for cultivation. Following the monsoonal rains in November, the reservoir begins to fill with water, and as the water level increases, the floodplains become inundated, making the area unsuitable for elephants from December to April. This is the time of lowest abundance in elephants. As water is released for cultivation in May, the declining water level in the Park substantially increases the carrying capacity of the Park. Elephants move in from outside. The gradual build up leads to Minneriya supporting elephants at a crude density of 3.6 animals per sq. km. This is among the highest densities recorded in Asia. In Africa, Douglas-Hamilton (1973) recorded elephant density of 5 animals per sq. km in Lake Manyara

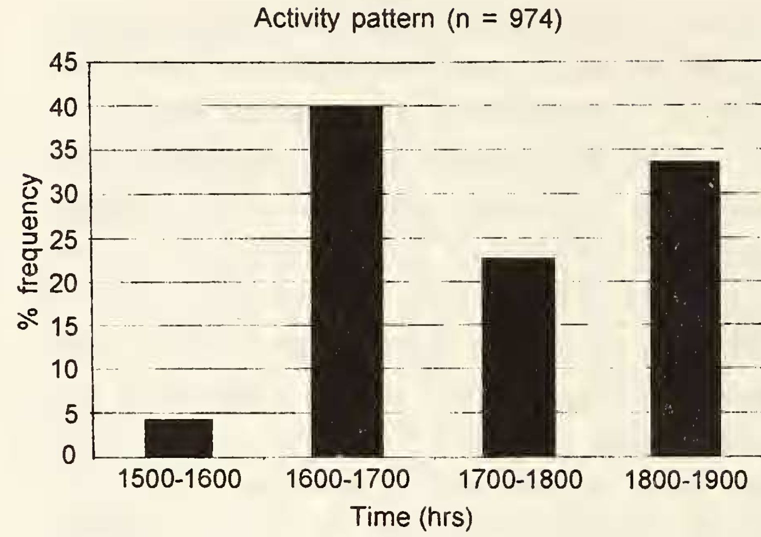

Fig. 5: Activity pattern of the elephants (both bull groups and herds) in Minneriya National Park

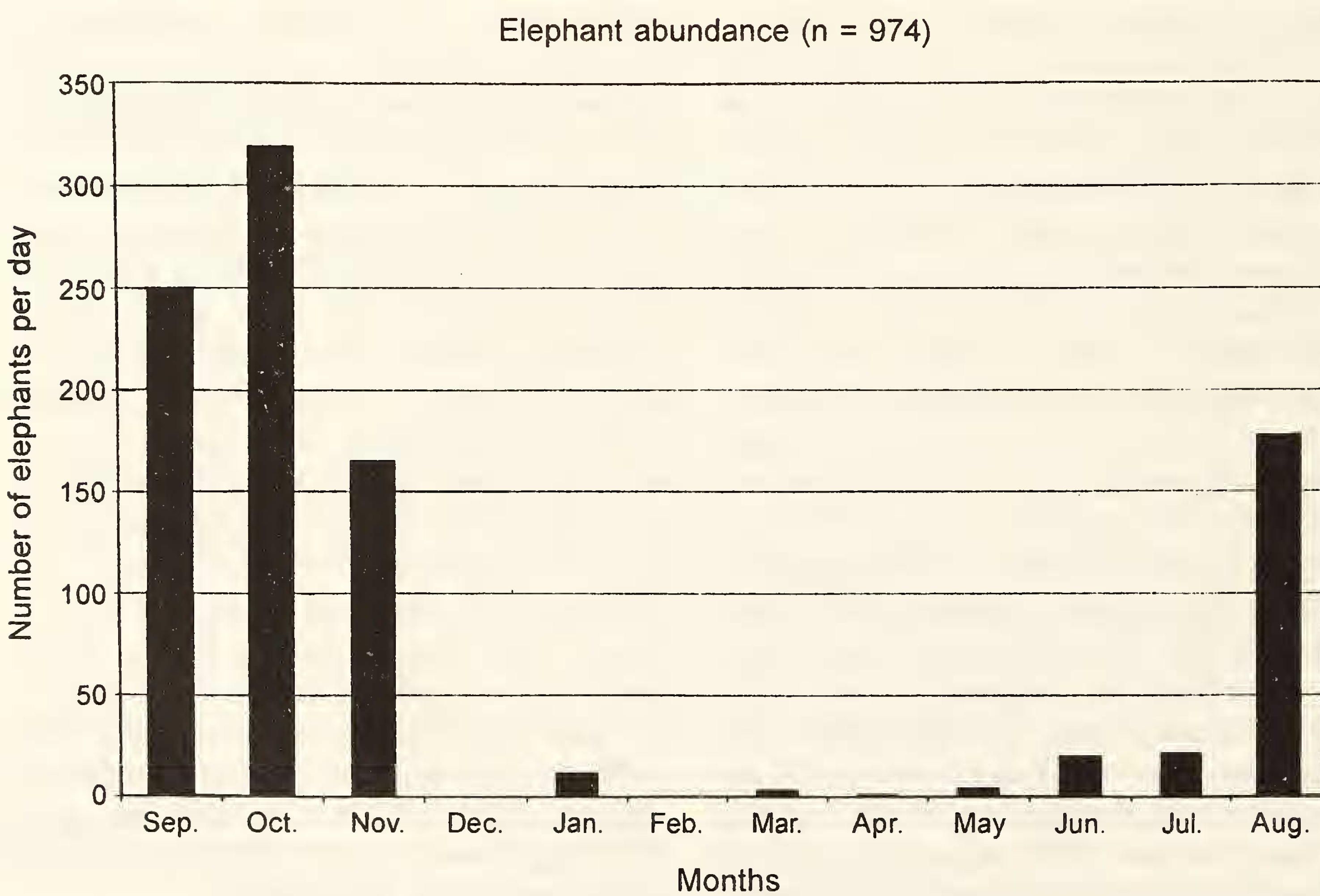

Fig. 6: Changes in elephant abundance in Minneriya National Park from September 2000 to August 2001

National Park, Tanzania. Elsewhere in Sri Lanka, the values estimated for elephant density range from 0.17 per sq. km in Gal Oya National Park in the east (McKay 1973), 0.46 per sq. km in Block I of Ruhuna National Park in the southeast (Santiapillai *et al.* 1984), and 0.12 per sq. km in Wilpattu National Park in the northwest (Eisenberg and Lockhart 1972). These density values highlight the importance of Minneriya as a conservation area for elephants in Sri Lanka. As Seidensticker (1984) points out, the water level relative to the floodplain and the slope of banks in reservoirs will determine the capacity of a catchment area to support elephants. The seasonal adjustment of water levels in Minneriya reservoir has resulted in the provision of grazing grounds for elephants, thereby making the Minneriya National Park one of the crucial conservation areas in north central Sri Lanka.

Assuming a minimum elephant population of about 300 during the peak period, and an average weight of 1,800 kg for each animal, the elephant biomass in Minneriya amounts to 540 metric tonnes and the average biomass density is 0.16 tonnes per sq. km. However, as elephants spend relatively long periods of time in very small areas, the ecological densities of elephants in grasslands can be substantially higher. Although artiodactyls such as wild pig, water buffalo, spotted deer, barking deer and sambar are present, their numbers are low, and their populations are thinly distributed across the Park. Hence the elephant remains the most important terrestrial herbivore. Its importance in Minneriya stems from its enormous size, intemperate appetite and its high mean age of survival, which as Watson and Bell (1969) point out, enable the species to make relatively massive interventions in terms of a diversion of energy flow in an ecosystem.

Conclusion

Elephants have been the *raison d'être* for the establishment of Minneriya National Park. Despite its small size, it is one of the important conservation areas in Sri Lanka that is able to sustain large numbers of elephants seasonally. It is an important area for the survival of a number of populations of elephants residents outside its boundaries, as it provides food, cover and water. The annual arrival and association of elephants in Minneriya during the rainy season makes the Park an *entrepot* where gene exchanges between unrelated bulls and family units are possible. Such genetic exchanges would improve the genetic fitness of the population and help keep inbreeding depression to a minimum. Furthermore, as Dublin (1996) argues, elephants may aggregate periodically in order to maintain and strengthen bonds or establish dominance hierarchies within kin groups. The fact that elephants at times were either low in number or not observed at all indicates that they, if not migratory, do undertake at least extensive movements within a large home range (Wyatt and Eltringham 1974).

The farming community in the periphery also exploits the rich grazing grounds: their herds of domestic buffalo are allowed to graze inside the Park. There are some 200 domestic cattle competing with elephants. Fortunately, there were no signs of overgrazing caused by cattle, as has been reported in Gal Oya (McKay 1973), to an extent that elephants must scarify the ground in order to feed on the short grass. Nevertheless, the number of domestic cattle needs to be controlled in order to prevent overgrazing in the future. Otherwise, heavy grazing will probably lead to a degradation of this rich grazing area and replacement of native grass by the less palatable *Imperata cylindrica.* Given the proximity of the Park to agricultural and human settlements, the long term survival of the elephant in Minneriya National Park can only be assured if management authorities ensure not only the welfare of the ecologically most dominant herbivore and its habitat, but also that of the people who compete with it for the limited resources of the land.

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